

DESIGN OF A FOAM
FIRE EXTINGUISHER SYSTEM

BY

G. B. JAMES

ARMOUR INSTITUTE OF TECHNOLOGY

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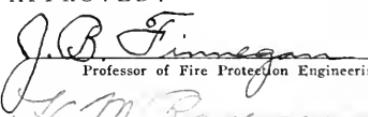
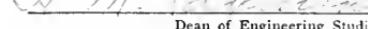
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DESIGN
OF A
FOAM FIRE EXTINGUISHER SYSTEM
—
A THESIS
—
PRESENTED BY
GARRETT BELL JAMES
TO THE
PRESIDENT AND FACULTY
OF
ARMOUR INSTITUTE OF TECHNOLOGY
FOR THE DEGREE OF
FIRE PROTECTION ENGINEER

May 27, 1920

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DESIGN OF A FOAM FIRE EXTINGUISHER SYSTEM

INTRODUCTION

The first oil fire in this country occurred in the year 1861 and as the production of crude oil and petroleum products increased the oil fire losses seem to have increased proportionally. Accurate and complete records of oil fire losses dating back to the year of the first oil fire are not available but information regarding those incurred in the last few years is published.

According to Bureau of Mines Bulletin 170, by Mr. C. P. Bowie, during the period of ten years between January 1, 1908 and January 1, 1918, approximately 12,850,000 barrels of oil and 5,024,506,000 cubic feet of gas were destroyed by fire in the United States, entailing a total estimated property loss of over \$25,000,000. This record includes 503 fires, but does not account for numerous small gasolene

fires.

The enormous conflagrations from oil fires and the tremendous losses which have resulted in the past can now be almost entirely obviated and controlled by a comparatively new system of oil tank protection, known as the foam system. Many of the largest oil companies in this country and others have installed, or are installing, such a system, and it is rapidly becoming recognized that the foam method is the only practical method for coping with oil fires.

Any expenditure for fire protection is wasted unless the protection is efficient and adequate. As foam is now used in connection with fire protection for several thousand oil storage tanks, and as engineers have learned by experience the best methods to be followed in order to get efficient results and the benefit of the positive protection afforded by the foam system, it is important to point out some of the fundamental requirements which have been found to be necessary to install a foam system properly.

FEATURES OF DESIGN

GENERAL

The foam system may be defined as a stationary foam-type chemical fire extinguishing installation having as its principle the generation and application, to a fire, of a blanket, or layer, of fire-smothering foam consisting of comparatively durable, minute bubbles containing carbon dioxide (CO₂). The foam is created by the reaction between two chemical solutions "A" and "B".

The essential components of a foam fire extinguisher system are as follows:- foam chemical solutions, solution storage tanks, solution pump (or pumps), solution pipe lines and devices from which foam may be distributed and applied. In case of fire, the two foam chemical solutions, which are stored in separate tanks, are pumped separately or discharged by gravity, in equal volumes through double pipe lines to mixing chambers, semi-automatic heads, combination nozzle sets, sprinkler heads or manifold

sets in which they combine and from which the resulting foam is applied.

FOAM CHEMICAL SOLUTIONS.

Since the introduction of the foam fire extinguisher system a number of different formulae for chemical solutions have been experimented with in order to determine the best two solutions that in combination will produce a tough, durable, tenacious foam. The inflating gas employed must be a non-supporter of combustion. In the following formulae which have been tried the components are on the basis of weight:-

Formula 1

Solution "A"

Aluminum sulphate (crystal)	12%
Powdered Extract Licorice	2.5%
Water	85.5%

Solution "B"

Sodium bicarbonate (pure)	8.5%
Water	91.5%

Formula 2 (U. S. Government Specification)

Solution "A"

Water	100 parts
Aluminum sulphate	12 parts
Acetic acid	$\frac{1}{2}$ part
Glue	1 part
Glucose	$\frac{1}{4}$ part

Solution "B"

Water	100 parts
Sodium bicarbonate	10 parts
Glue	1 part
Glucose	$\frac{1}{4}$ part

Formula 3 (Standard Oil Co. of California)

Solution "A"

Aluminum sulphate	10.5%
Sulphuric acid	0.5%
Water	89.0%

Solution "B"

Arsenious oxide	0.02%
Glucose	0.53%
Glue	1.45%
Sodium bicarbonate	8.00%
Water	90.00%

Formula 4 (Foamite Firefoam Co.)

Solution "A"

Aluminum sulphate	13%
Water	87%

Solution "B"

* Foamite	3%
Sodium bicarbonate	8%
Water	89%

* Foamite is a secondary extract of licorice root treated by a special process and concentrated.

Formula 2 and Formula 3 have been found to be undesirable as all of the glue solutions deteriorate rapidly on standing, even when they contain arsenious acid equivalent to 150 lbs. per 1200 barrels of solution.

Solutions made according to Formulae 1 and 4 give foam of equal quality and quantity. The durability of foam made with Foamite seems to be superior. Foamite dissolves more readily than powdered extract of licorice, which costs from five to six times that of Foamite. The "A" Solution, specified in Formula 4, does not

deteriorate with age and the "B" Solution requires only the addition of a small quantity of sodium bicarbonate about once a year. Foamite Firefoam Company employ Formula 4 and the two solutions are of such concentration that when equal volumes of each are mixed they produce approximately eight times their combined volume of tough, durable, tenacious carbon dioxide foam. The maximum volume of foam is obtained when the solutions are at a temperature between 80° and 90°F.

AMOUNT OF SOLUTIONS

One of the most vital points in the design of a foam fire extinguisher system is to have an ample supply of the foam-producing solutions as the quantity of these is in one sense the measure of the protection the system affords. The cost of the chemicals is slight and the difference in cost of larger solution tanks, when compared to the total cost of a foam system, is such a small item it would not be thought necessary to call attention to the desirability of making them as large as possible. Nevertheless,

there are a number of plants where the chemical solution tanks are entirely inadequate and the owners are deceiving themselves into thinking they have real foam protection. It is not only necessary to provide the theoretical quantity required, but also to have a large factor of safety to provide for the unexpected occurrences peculiar to oil fires. The quantity of chemical solutions to be provided will, of course, vary with the conditions encountered and following are general rules based on practical experience.

Actual fires have shown that between 1 and $1\frac{1}{4}$ gallons of each foam chemical solution must be applied for each square foot of burning area, within a time limit of five minutes to extinguish an oil fire. In some instances twice this amount has been necessary.

In calculating the volume in gallons of each chemical solution to be provided, the following rules are applied to refinery premises, tank farm premises, isolated tanks, and on all risks involving oil in tanks:-

1.- Allow five gallons of each foam chemical



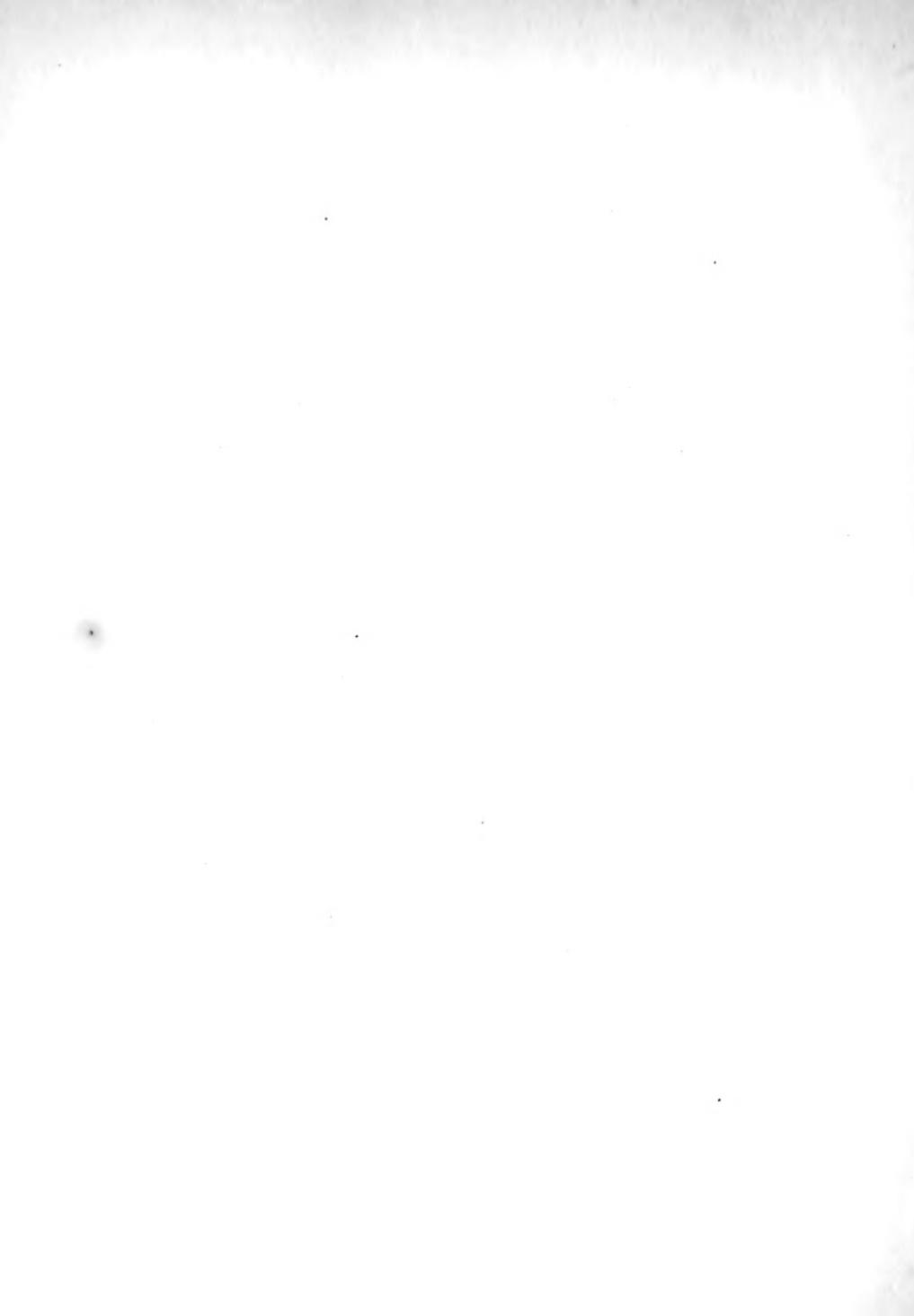
solution per square foot of surface for the largest single tank, which will be defined hereafter as the "Pivot Tank".

2.- Allow three gallons of each foam chemical solution per square foot of surface for all tanks lying within an "Exposed Distance" of one tank diameter of the Pivot Tank, and in the "Exposed Area", as hereafter defined:-

"Exposed Distance" is considered as extending from shell to shell, and as being expressed in terms of the diameter of the "Pivot Tank".

"Exposed Area" is considered to be the area represented within a quadrant, the apex of which lies at the center of the Pivot Tank. The bisecting line of this quadrant is assumed to represent the direction of the wind. This line should lie in the direction which will obtain the greatest amounts of solutions when this ruling is applied.

3.- Allow two gallons of each foam chemical solution per square foot of surface for all tanks



lying within the Exposed Area at an Exposed Distance of more than one diameter and less than two diameters from the Pivot Tank.

4.- Allow one gallon of each foam chemical solution per square foot of surface for all tanks lying within the Exposed Area at an Exposed Distance of more than two diameters and less than three diameters from the Pivot Tank.

5.- If the total area of oil surface to be protected exceeds five times, and is less than fifteen times, the area of the Pivot Tank, add 20% to the total amount of each foam chemical solution obtained from the foregoing calculation.

If the total area of oil surface to be protected exceeds fifteen times, and is less than twenty-five times the area of the Pivot Tank, add 40% to the total amount of each foam solution obtained from the foregoing calculation.

If the total area of oil surface to be protected exceeds twenty-five times, and is less than thirty-five times, the area of the Pivot Tank, add 60% to the total amount of each foam solution obtained from the foregoing calculation.

If the total area of oil surface to be protected exceeds thirty-five times, and is less than forty-five times, the area of the Pivot Tank, add 80% to the total amount of each foam solution obtained from the foregoing calculation.

If the total area of oil surface to be protected exceeds forty-five times, the area of the Pivot Tank, add 100% to the total amount of each foam solution obtained from the foregoing calculation.

SOLUTION TANKS

If steel tanks were employed for the storage of the foam chemical solutions it would be necessary to place a lead lining in the tank containing the aluminum sulphate owing to its corrosive action on steel. Bituminous enamel has been tried in some cases but unless the coating can be maintained without cracks it is practically useless. The expense of steel tanks is another item which renders their use almost prohibitive.

The tanks most used for storing the solutions are of a capacity generally not exceeding 52,000 gallons each; usually constructed

of redwood, cypress or fir, preference being given to redwood. In specifying these tanks the standard of the National Board of Fire Underwriters for gravity tanks should be followed as far as practicable. The tanks are constructed of 3-inch lumber, dressed to $2\frac{3}{4}$ inches. Round wrought iron hoops and adjustable malleable iron tightening lugs are employed. This hoopage should be so figured that the maximum stress at the base of the thread does not exceed 12,500 lbs. per square inch when the tank is filled to the top with liquid having a specific gravity of 1.074 at 60°F. All hoops and tightening lugs are coated with a non-corrosive, asphalt paint previous to being put in place, and again after they are in position. The usual practice is to employ yellow pine dunnage and this should be brush treated before being placed. All piers and dunnage should be of such size that the stress in compression or tension does not exceed 900 lbs. per square inch.

Tanks erected in climates where freezing is liable to occur should be equipped

with a heating coil and a double frost-proof cover as specified in the standard of the National Board of Fire Underwriters, or located in a heated building. In no case should the temperature of the solutions be allowed to fall below 50°F. As sodium bicarbonate may be decomposed, if heated above a certain temperature, it is advisable that an indirect system of heating, as is used in some sprinkler tanks, be employed. Water which has been heated by steam is circulated through a coil at the bottom of each tank. All tanks are painted outside, with a non-corrosive bituminous paint. Foam chemical solution tanks should be located as near as practicable to the foam pump house and otherwise unexposed.

MIXING TANK

Where large amounts of the chemical solutions are to be stored, it is very convenient to have installed a comparatively small mixing tank in connection with the solution tanks. In this the solutions can be prepared

and then pumped into the storage tanks.

This mixing tank should be sunk in the ground so that its top is flush with, or several inches above, the ground level. A grating can be placed over the top of this tank. When solutions are to be prepared, the tank is filled to the proper depth with fresh water at a temperature between 80° and 100°F. Air agitation is then started and the weighed chemicals added slowly. When the solution is complete it may be pumped into the main solution tank, or tanks.

FOAM SOLUTION PUMPS

It is not only necessary to have on hand plenty of the chemical solutions, but also to be able to mix and introduce them into the tanks in a limited time and in equal quantities. Time is an essential factor-first, because the foam must be introduced into the tank faster than the fire can destroy it so as to smother the fire; and, second, so that the tank may not be overheated and begin to crumple and destroy the

foam connections before the foam extinguishes the fire.

Further, a particular type of pump must be used which will discharge exactly equal amounts of both solutions, as the solutions are of such strength that the alkali of one and the acid of the other will make a foam of maximum volume and permanence. Except in rare cases, this practically prohibits the use of separate pumps, for each solution, as centrifugal pumps, or any device which does not insure absolutely equal discharges of the two solutions. An excess of one chemical or the other produces a watery foam due to the uncombined liquid it must carry with it, and such a foam does not possess the permanence of a "dry foam" such as is produced by equal quantities of the solutions. One installation in West Virginia, covering three 55,000 barrel tanks, one 37,500 barrel tank and three small tanks, has two separate foam pumps for the solutions and each has a capacity of 65 gallons per minute. Although the company has expended a considerable sum for the

installation they have no protection. In the first place the pumps are entirely too small to deliver the solutions through the pipe lines with sufficient rapidity to produce foam faster than the fire would destroy it; and in the second place it is impossible to run two separate pumps at exactly the same speed, and what foam was produced would be of the most indifferent character.

The sizes of the pump and lines should be figured as sufficient to cover a tank in from five to ten minutes, according to the distance of the tank from the pump. As is evident, it is necessary to have the pump arranged so that the suction and discharge of each cylinder is separate. In order to insure that as nearly as possible equal quantities of each solution enter the mixture, either a twin duplex pump or a fly wheel pump should be used to avoid the effect of short stroking, which often occurs in the ordinary duplex type. Unless equal quantities of each solution are pumped, the full amount of foam is not produced and the uncombined excess of

either solution affects the quality of the foam.

It is essential that the pump cylinders handling the aluminum sulphate solution be made either of bronze or bronze fitted owing to the corrosive action of this solution. Automatic relief valves must be placed in the discharge lines from the pump to prevent excess pressure bursting the piping. Pumps especially designed for this work are built by several pump manufacturers and one make seems to be very popular.

In the practice of one large company that specializes on the design of foam systems the capacity of a pump selected for an installation is such that it will deliver $\frac{1}{4}$ gallon of each of the two foam chemical solutions for every square foot of burning area on the largest unit risk within five minutes' time, while operating at its normal rated speed. The pump capacity, in gallons per minute of each solution, is figured from the equation:-

$$\text{Pump capacity} = \frac{A}{4 \times 5}$$

where A is the area of the largest unit risk, expressed in square feet. Dividing A by 4 gives

the number of gallons of each solution to be supplied in five minutes, and division by 5 gives the volume, in gallons, of each solution to be supplied in one minute.

Positive displacement pumps, preferably of the piston type, are generally selected. The pistons handling each solution being of the same diameter and operating at the same speed displace equal volumes, thus metering the proper amount of chemicals to produce the best foam. Such pumps may be steam or power driven.

A pump of the twin duplex type is employed in the majority of foam installations. In steam practice the valve area is considered as the factor for determining the pump capacity. The pump should be selected so that the maximum velocity of the solutions through the valves, when the pump is delivering the required capacity, shall be not greater than 200 feet per minute. This is considered as a safe velocity. The fluid pressure against which the pump must operate is the sum of the friction loss in delivery pipe

lines, when the pump is being operated at its rated capacity, plus 50-feet entrance head into mixing chambers. The pump must also be capable of delivering 50 gallons of each solution per minute from the most distant foam solution hydrant with a nozzle pressure of not less than 50 pounds per square inch, when all other foam outlets are shut off.

The friction loss through the pipes for the solution is calculated to be from 6 to 10% in excess of water friction. This is due to the fact that the solutions have a viscosity approximately 6% greater than that of water.

Below is an example of the practice followed in selecting a suitable pump from among several standard sizes which have a rated capacity of 500 gallons per minute at a piston speed of 100 feet per minute.

Example:- Assume, steam pressure of 80 lbs., fluid pressure of 125 lbs. and a mechanical efficiency of 75%. Desired to select pump from four having diameter of steam cylinders 15, 16, 18 and 20 inches respectively. The

following equation is used:-

$$P \times D^2 \times E = p \times d^2 \times 2$$

$$\text{or } D = \sqrt{\frac{p \times d^2 \times 2}{P E}}$$

where D = Diam. of steam cylinder, inches.

d = Diam. of fluid cylinders, inches.

P = Steam pressure, lbs. per square inch.

p = Fluid pressure, lbs. per square inch.

E = Mechanical efficiency of pump.

Factor 2 used because pump has two ends.

Substituting:- $D = \sqrt{\frac{125 \times 64 \times 2}{80 \times .75}}$

Solving:- $D = 18.6$ inches.

Therefore a pump $20 \times 8 \times 8 \times 18$ would be used.

In general, the following fittings should be called for on all foam solution pumps:-
For each fluid end, Tobin bronze piston rods, bronze piston and follower, removable (bolted in) bronze cylinder liners (except on pumps smaller than $7\frac{1}{2} \times 5 \times 5 \times 10$, where a pressed tube bronze liner is allowed), bronze valve seats, bronze valves, bronze valve stems and bronze springs. In the fluid end for handling

aluminum sulphate solution the piston and follower should be fitted with 3 rings of bronze metallic packing. In the fluid end for handling sodium bicarbonate solution the piston and follower is fitted with fibrous hydraulic packing.

Each pump should be fitted with three pressure gauges, one for each fluid and one for steam; suitable drain cocks for cylinders, sight feed lubricator, air chambers and bronze relief valves in each discharge line. The relief valves should be connected into their respective suction lines.

In comparing one of the standard size foam pumps, namely 500 gallons per minute of each solution, with a National Standard pump of the same rated capacity, we note that the foam pump has fluid cylinders 8 x 18 inches, valve area of 28 square inches and fluid velocity through the valves of 172 feet per minute, while the National Standard pump has fluid cylinders $7\frac{1}{4}$ x 12 inches, valve area of 23.11 square inches and a fluid velocity through the valves of 208 ft. per minute. All pumps for use in foam

systems should be designed for a working pressure of 200 lbs. per square inch but a pressure to exceed 150 lbs. per square inch is seldom used. In pumping great distances, 150 lbs. per square inch might be exceeded.

In the determination of the brake horse power of driving units for power driven pumps the following equation is employed:-

$$B. H. P. = \frac{2 \times Q \times W \times H}{33,000 \times E}$$

where B. H. P. = Brake horse power.

Q. = Gallons per minute of each sol.

W. = Weight of one gal. of sol. in lbs.

H. = Max. working pressure in ft. head.

E. = Mechanical efficiency of pump.

The weight of one gallon of "A" solution = 8.96 lbs., while the weight of one gallon of "B" solution = 8.85 lbs. The mechanical efficiency of reciprocating pumps is figured as 80% when pump is delivering rated capacity. For rotary pumps E is figured as 50% to 60%.

All pumps should be arranged for

priming from the solution tanks by gravity. All units should be installed and tested in accordance with the regulations of the National Board of Fire Underwriters, as far as they are applicable. Pumps should be located in a fire-proof room, cut off from the rest of the plant, in an approved manner and accessible from the outside, or in an unexposed separate brick (or its equivalent) building.

If avoidable, centrifugal pumps should not be used for foam chemical solutions as they are not of the positive displacement type, inefficient in small sizes, and difficult to manipulate to secure the same friction loss in the two solution lines. Single stage centrifugal pumps were recommended in one case, in place of a reciprocating unit, as a pump capacity of 3000 gallons per minute of each solution was required with the pump working under a low head. In this case, the specifications included Venturi tubes, on each discharge line, fitted with differential ^{that} mercury gauges, ~~would have been arranged in~~

such a manner that the operator could readily tell how much solution was being discharged by each side of the pump. The discharge valves were to have been so located that they could be throttled until the gauges indicated that an equal quantity of solution was being discharged by each side of the pump. Such a unit would consist of two pumps with an electric motor in between.

Rotary pumps, if considered as an alternate for piston pumps, should be of the dual eccentric cam type and two similar pumps be interconnected by gears and driven by one prime mover.

PIPING, VALVES AND FITTINGS

Standard weight wrought steel pipe, bronze or bronze fitted valves, and cast iron fittings are most suitable for field piping. Malleable iron fittings may be preferable for use in the solution lines at the mixing chambers, as well as at the joint immediately below the mixing chamber at the ground, on account of



their proximity to the fire. The pipe lines obviously must be calculated to be of adequate size to permit the pump to discharge the proper amount of each solution at the fire, allowance being made for the friction head (6 to 10% in excess of water friction) in the pipes and the lift to the tanks of 50 feet. All valves in the pump house and field should be either rising stem gate valves or valves with approved indicators, and the quality of the pipe, valves and fittings used should comply with the standards of the National Board of Fire Underwriters.

All field valves should be located by conspicuous markers. These might well be constructed of 4" x 4" wood posts (or their equivalent) at least 8' high, carrying panel-boards indicating the number of the tanks controlled. Posts should be painted red; panel-boards should be painted white and lettered with a dark color. Another essential requirement in regard to valves is that the route ^{to} _{of} all valves be kept clear of any and all obstructions. All pipe lines inside of fire walls around tanks

should be covered with earth to a depth of at least two feet. This is to prevent the pipes from bursting in case any oil should get into the area within the dike and should catch fire.

When the field piping is installed drains should be located at low points to permit drainage of any accumulated condensate. Valves in the field pipe lines leading to semi-automatic mixing chambers should be wired open, so that they cannot be accidentally closed.

The heating coils in the solution storage tanks should be of lead and the suction lines, pipe fittings and valves, which contain aluminum sulphate solution should be either lead-lined or otherwise suitably acid-proofed. The suction lines for each chemical solution may be easily protected from freezing by being placed in the underground conduit through which the heater pipe passes.

Plate No.1 illustrates an incorrect and correct way of piping up to a mixing chamber. At first glance it might seem that there is little to choose between the two methods, yet

it may mean the loss or saving of a tank. The essential difference is that the chemical solutions may be cut off or turned into either mixing chamber when correctly piped up, while in the other they must be turned into both or neither. In a certain case in Texas a tank was equipped as shown in No.1. The tank was ignited in an electrical storm and the roof blown off, destroying one of the mixing chambers. There was no means of cutting off the flow of solutions from the broken connections, so they flowed out on the ground and deprived the other mixing chamber of much of its supply. Although the fire was finally put out it required six hours and the loss was heavy. With the correct piping, in this case, the solutions could have been shut off from the broken mixing chamber and the flow of chemical solutions to the other chamber would not have been affected.

The pipe connections between the foam solution pump, solution tanks, mixing tank, air compressor and steam and water supply lines should be so arranged that any of the following

operations may be accomplished by the manipulation of proper valves:-

Operation No.1. - Connect pump suctions to their respective foam solution tanks, and connect pump discharges to the main outgoing supply lines which lead to the oil tanks and hose stations. This is used in case of fire.

Operation No.2. - Connect pump suctions to the main discharge lines, and connect pump discharges to the suction lines extending to the solution tanks. This connection is used after a fire to salvage as much as possible of the chemical solutions remaining in the lines, returning them to their respective solution tanks.

Operation No.3. - Connect pump suctions to the fresh water supply, and connect pump discharges to the main solution lines. This connection is used, after the maximum amounts of residual solutions have been salvaged from the pipe lines, to force fresh water through the pump and all pipe lines, thoroughly washing them.

Operation No.4. - Connect air with main discharge solution lines. This connection is used in

drying out the pipe system after salvaging the solution and washing out with water.

Operation No.5. - Connect fresh water supply to the mixing tank. This connection is used when filling the mixing tank with water. Connect steam supply with the mixing tank. This connection is used for heating the water in the mixing tank.

Operation No.6. - Connect the pump suction to the mixing tank and the pump discharge to the solution storage tanks. This connection is used when charging the solution tanks. Care must be used not to pump Solution "B" into Solution "A" tank, or vice versa, when drawing solution from the mixing tank and discharging it into one of the solution storage tanks.

MIXING CHAMBERS

There is no one feature of the foam system which has been less understood than the proper method of producing the foam and of introducing it into the tanks and even today more foam systems are inadequate for this reason than

any other. In a general way the foam must be made at the point it is to be used. The mixing chamber must be large enough for the reaction to be completed before the foam is discharged into the tank, and it must be allowed to fall on the oil with the least velocity so that it will not be driven under the oil surface. The means used for producing the foam must further be of such a character and so located that they will be reasonably safe from destruction from an explosion, falling roofs, or of being burned before the foam solutions reach them.

In the early days of foam development it was thought that foam could be introduced into the tanks through pipes. One of the piping arrangements widely used in Texas is shown in Plate No. 2. This method was applied to 55,000 barrel steel tanks of 114 feet 6 inches diameter. After this had been criticized a test was made and a most indifferent, watery foam was produced. It is not advisable to pass foam through pipe lines under pressure, particularly if the line contains bends. As a

concrete example of this point attention might be called to the following account of a fire at a refinery in New Jersey:- The tank was 37,500 bbl capacity, 93 feet in diameter and contained 17 feet of Pennsylvania crude oil. The tank was struck by lightning and the roof was partly blown off. Immediately efforts were made to introduce foam through four 2 inch pipes, but without any appreciable results. Fifty minutes after the fire started a three-inch pipe line was discharging foam over the side of the tank, and twenty minutes later another similar line was put in service. The tank and its contents were, however, destroyed. This, too, in spite of the fact that 15,000 gallons of each solution were used. One-tenth of this amount should have been sufficient, and shows that failure was due entirely to the inadequate means used.

One form of mixing chamber which, though quite widely used, leads to a false idea of having foam protection, is shown in Plate No. 3. Many tanks are equipped in this manner as it was one of the earliest methods used.

It has several inherent objections, one of these being that it requires considerable labor to install owing to the necessity of removing a portion of the roof or emptying the tank. This, however, is a minor matter compared to the fact that in case of fire these mixing boxes are exposed to the full heat of the fire and may be destroyed even before the sides of the tank, and, furthermore, may be torn off should the roof fall in. During July, 1917, a fire occurred in a 55,000 bbl. tank in Texas. This particular tank had a wooden roof. There was only a comparatively small amount of oil in the tank when it was ignited by lightning and this was extinguished in a few minutes by foam. However, the wooden roof was on fire on the lower side and there was no means available to extinguish it. It burned and fell, but upon doing so it carried down with it the two mixing ^{chambers} and the mass of blazing wood reignited the oil. No foam could be produced within the tank without the mixing boxes, and although large quantities of foam solutions were pumped into the tank they

naturally had no more effect than so much water, and the tank was destroyed.

In order that the foam produced by the reaction of the two chemical solutions may be properly applied to a fire, it is desirable to produce it as near the fire as possible, have the chemical reaction completed before the foam reaches the fire, and subject the foam to as little rough usage as possible. For tanks of twenty-five feet, or greater, in diameter the foam is usually applied through mixing chambers. These chambers should be placed on the outside of a tank and attached to the angle iron around the top of the tank, as shown on Plate No.4. The two solutions enter the chamber, at the bottom, from two pipes connected to the main solution lines which are located outside of the fire wall or earthen embankment. The control valves are located near the main solution lines. For details of construction of these mixing chambers and method of attachment to tanks see Plate No.4. As indicated, the mixing chambers are made in three standard sizes, known

as Type NA, Type MA and Type LA. The general practice in the application of mixing chambers to different size tanks is given in the schedule below:-

<u>No.</u>	<u>Type</u>	<u>For tanks</u>
1	NA	10 to 29 ft. in diam.
1	MA	29 to 55 ft. in diam.
1	LA	55 to 70 ft. in diam.
2	MA	70 to 92 ft. in diam.
2	LA	92 to 115 ft. in diam.

In general, the mixing chambers should be so located on the tank that the foam generated in them may be discharged into the tank, over the angle iron around the top of the shell, through an opening in the roof. In order that the tank may be kept gas-tight at the place where the mixing chamber is attached flashing should be placed over the roof and around the top of the chamber. By this arrangement the mixing chambers will remain serviceable should the roof be blown off by an explosion.

Mixing chambers arranged as indicated above are always accessible for inspection, repairs or painting.

SEMI-AUTOMATIC HEADS

The semi-automatic duplex head installed by the Foamite Firefoam Company of New York is shown in detail on Plate No.5. It consists of a double sprinkler head placed inside of the tank and surrounded by a semi-circular plate as shown by Plate No.6. In case of fire in the tank, the fusible strut is melted allowing the device to operate thus opening the orifices in the head. The bronze caps over the openings rest on lead seat-rings. The solder used on the fusible struts melts at approximately 280°F. Solder of this high a melting point is employed to avoid release of the head while the tank is being steamed out. After the fusible strut has operated and the pump has been started the solutions can be pumped to the burning tank as the valves to that particular tank or group of tanks are wired open, as previously noted. The solutions from the orifices come in contact

with each other, causing a spray to be projected against the shell of the tank and the semi-circular plate. This results in further mixing of the solutions and the foam generated falls lightly onto the surface of the burning material in the tank.

Should an adjoining tank become heated sufficiently to cause the opening of the head, foam will be automatically distributed over the surface of the tank contents. Semi-automatic heads may be placed on tanks where, owing to local conditions, it is necessary to lay the main solution pipes so close to the tanks that a man would have difficulty in approaching close enough to operate the control valves during a fire. Semi-automatic heads are generally installed on groups of small tanks or on tanks where their use will greatly simplify or reduce the cost of piping. This device can be adapted for an entirely automatic system similar to a dry-pipe sprinkler system.

The semi-automatic heads are now built in two sizes, namely:- Type SA, having orifices

1 inch in diameter, and Type SB, having $\frac{1}{2}$ inch orifices. The general practice followed in the application of semi-automatic heads to different sizes of tanks was developed after numerous experiments. Following is the schedule used in the design and installation of such heads to various size tanks:-

<u>No.</u>	<u>Type</u>	<u>For tanks.</u>
1	SB	Up to 15 ft. in diam.
2	SB	15 to 30 ft. in diam.
1	SA	15 to 40 ft. in diam.
2	SA	40 to 60 ft. in diam.
3	SA	60 to 75 ft. in diam.
4	SA	75 to 90 ft. in diam.

MANIFOLD SETS

Another manner in which foam may be introduced into a burning tank is the manifold set. This is a pipe manifold in which the two foam chemical solutions are mixed and from the branches of which pipes lead to small tanks to which it may be desired to apply foam. The large mixing pipe, six to ten inches in diameter,

is connected at one end to the two solution lines and at the other, by means of a reducing elbow, to a number of pipes $2\frac{1}{2}$ to 3 inches in diameter.

A manifold set may be used to render protection for a group of small tanks. In case of a fire, the valves are opened allowing the solutions to flow into the mixing tube, and the foam generated is discharged through a branch from the manifold into the tank where the fire is located by opening the valve leading to that tank. The foam pipes should be made as short as possible in order that the foam produced in the large pipe may not be seriously broken down. In general practice this form of foam distribution should not be placed on any tank over 30 feet in diameter. The large mixing pipe should be located at least 50 feet from any tank, still, building, condenser, etc. to be protected owing to exposure in case of fire.

HOSE STATIONS, FOAM SOLUTION HYDRANTS AND NOZZLES.

No foam system can be considered adequate which does not supplement the permanent

mixing chambers by flexible means of applying foam in case the former are destroyed. In other words, hose connections must be provided, and must be placed at such points that any tank can be reached by them, and an adequate supply of foam of the proper character applied at will. This is particularly the case of wood-roofed tanks and the necessity of hose connections is further brought out by the accounts of actual fires mentioned later.

Foam hose stations should be located at suitable points in every foam system not nearer than 50 feet to any tank, still, building, condenser, etc. Hose stations should preferably be painted red and suitably designed. Each hose station should contain at least two lengths, 250 feet each, of one and one-half inch cotton rubber lined hose on reel, with mixing tube and siamese connection, also an extra play-pipe, spanner wrenches, mixing tube, lantern, pike-pole and such other necessary equipment. At least two 35 foot ladders should be provided and these should be kept in a suitable unexposed location.

Foam solution hydrants should be not nearer than 50 feet of any tank, still, building, condenser, etc., to be protected and at least two such hydrants should be situated within a radius of 400 feet of tank shell or of still, building, condenser, etc. Foam solution hydrants must have foam hose house within $\frac{1}{4}$ mile. Plate No.7 shows the assembly of a $1\frac{1}{2}$ inch hose hydrant angle valve as are found to be very serviceable in a foam system.

In the event of fire the operation of the hose streams is as follows:- Two lines of $1\frac{1}{2}$ inch cotton rubber lined hose are led from hydrant angle valves located in the main solution supply line and siamesed into a 5 foot length of $2\frac{1}{2}$ inch cotton rubber lined hose to which a standard play-pipe is attached. The two foam chemical solutions are pumped separately through the $1\frac{1}{2}$ inch hose and mixed in the short section of $2\frac{1}{2}$ inch hose and delivered from a 1 inch nozzle or standard play-pipe while the foam is still in the process of generation. The foam generation is completed while the mixed solutions

are traveling through the air or takes place almost immediately after the mixed solutions strike any surface.

OPERATION AND MAINTENANCE

While the foam fire extinguisher system is simple, being but an application of principles which have long been in use, with the addition of a new material, it may be highly desirable to point out a few points which should be observed in its operation and maintenance.

In Case of Fire.-1. Stir foam solutions for five minutes (no longer) by means of compressed air.

2. Open the valves in the two suction lines and two discharge lines. Start pump slowly and bring up to speed.

3. Open proper valves to permit flow of foam solutions to location of fire. When opening valves to foam mixing chambers, or hose lines, be careful to open wide the valves in both solution lines simultaneously.

4. Connect hose lines to the hose hydrant

stations nearest available to fire, and use hose stream when and where the occasion warrants,- for wooden timbers burning in the tank, and for burning oil on the ground around the tank. If nozzle pressure is low, allow mixing chambers to accomplish as much fire extinction as possible, then shut off flow to the mixing chambers and use hose streams.

After a Fire.-1. Salvage as much of the chemical solutions remaining in the pipe lines as possible, returning them to their respective solution tanks. (See Operation No.2, under heading, "Piping, Valves and Fittings.")

2. Wash out the pump and pipe lines thoroughly with fresh water. (See Operation No.3, under heading, "Piping, Valves and Fittings.")

3. Drain the used foam mixing chambers by removing plugs in bottom, provided plugs are used; replace plugs.

4. After washing thoroughly all the pipe lines, drain them and dry by means of compressed air. (See Operation No.4, under heading, "Piping, Valves and Fittings.") Wash and drain all used

hose and dry jacket before replacing hose on reels.

5. Recharge solution tanks to their full capacity.

Care and Attendance.-1. Operate the pump for five minutes once a week, opening drain cocks so that pump can run on air. Do not pump any of the solutions. Oil all working parts.

2. Stir the solutions with air on the first Saturday of every third month for not less than three nor more than five minutes.

3. Test the pump for capacity and pressure on the first Saturday of every third month. Suck solutions from the tanks and circulate them through the by-pass valves. The main discharge valves should be closed during this test to prevent the solutions from entering the field pipe system. Throttle the by-pass valves and observe whether the pump will operate at its rated piston speed when discharging the solutions against the rated fluid pressure. Throttle the by-pass valves until the relief valves open and note the pressure on each line. Close the by-pass

valves and pass the entire discharge through the relief valves and note the pressure on each line. Drain all the solution from the pipe connections. The pump and pipe lines, which have had solutions in them, must be washed thoroughly with water after this test. Thoroughly drain system.

4. All pipe lines should be subjected, at least semi-annually, to a hydrostatic test of 175 lbs. per square inch.
5. All hose should be tested for tightness at least once each year at from 100 to 125 lbs. static pressure.
6. Water should be run through all cotton rubber lined hose at least twice a year to retard deterioration of the rubber lining.
7. Drain all hose, and dry jacket before replacing on reels.
8. All precaution possible should be exercised to prevent the theft of any pieces of apparatus connected with the system.
9. Make foaming and hydrometric test of the foam chemical solutions twice a month as follows:--

Foaming Test:- Pour 25cc. of each

solution simultaneously into a graduated cylinder of about 500 cc. capacity. The temperature of each solution should be $70^{\circ}\text{F}.$, a maximum variation of one degree either way being permissible. The solutions should expand to at least six times their original volume (combined). The foam should consist of fine minute bubbles, should be quite stiff and should show no signs of collapse upon stirring.

Hydrometric Test:- Foamite Solution

"A" should have a specific gravity of 1.074 at $60^{\circ}\text{F}.$ when referred to distilled water at 60°F as standard. The equivalent in degrees Be' is 9.99. Foamite Solution "B" should have a specific gravity of 1.063 at $60^{\circ}\text{F}.$ when referred to distilled water at $60^{\circ}\text{F}.$ as standard. The equivalent in degrees Be' is 8.59.

10. Before freezing weather sets in, drain all mixing chambers by removing the plugs from bottom, provided plugs are used, thus removing any accumulation of condensate. Replace plugs. All pipe lines should be carefully drained at this time.

11. Any evaporation from either "A" or "B" solution should be replaced by a sufficient amount of fresh water to bring the solution to its original specific gravity as mentioned in paragraph 9, under the heading "Care and Attendance".

12. When the outside temperature falls below 50°F. the heating system for the foam solution tanks should be set in operation and the temperature of the solutions maintained at about 60°F. during the entire cold season.

CHARGING INSTRUCTIONS

Solution "A".

Allow water to run into the mixing tank to the required depth, then heat the water with steam. (See Operation No.5 under heading "Piping, Valves and Fittings.") Continue heating with steam meanwhile adding water in sufficient quantity so that when the water in the tank reaches the required depth it will have a temperature of about 100°F. Start stirring by means of air or with a long pole and add slowly stipulated amount of aluminum sulphate. Con-

tinue stirring until thoroughly dissolved. When dissolved, pump the solution into the Solution "A" tank and stir with air. Repeat the operation until a sufficient amount of aluminum sulphate has been dissolved. Moderate air stirring in the Solution "A" tank should be continued until the charging is finished.

Solution "B".

Fill the small mixing tank with the required amount of warm water in the same manner as for Solution "A", and start stirring either by means of air or with a long pole. Add slowly the stipulated amount of sodium bicarbonate and stipulated amount of Foamite and stir thoroughly until dissolved. The sodium bicarbonate must be completely dissolved before adding the Foamite. When dissolved, pump the solution into the Solution "B" tank. Repeat the operation until a sufficient amount of sodium bicarbonate and Foamite has been dissolved. Continue moderate air stirring in the Solution "B" tank until the charging is completed. Excessive air agitation is injurious to the "B" solution.

Foamite chemical solutions are made up according to the following formulae, the components being upon a basis of weight:-

Solution "A"

Aluminum sulphate	13%
Water	87%

Solution "B"

Sodium bicarbonate	8%
Foamite	3%
Water	89%

If a portion of the Foamite solutions have been consumed during a fire, the recharge should be mixed in the mixing tank according to the following data:-

For each gallon of Solution "A" to be added to the Solution "A" tank the recharge is

Aluminum sulphate	1.163 lbs.
Water	0.936 gal.

For each gallon of Solution "B" to be added to the Solution "B" tank the recharge is

Sodium bicarbonate	0.708 lbs.
Foamite	0.265 lbs.
Water	0.945 gal.

Each lot of solution made up in the mixing tank should be tested with the hydrometer as specified in paragraph 9, under heading "Care and Attendance".

Care must be used not to pump solution "B" into Solution "A" tank or vice versa when drawing solution from the mixing tank and discharging it into one of the solution storage tanks.

GENERAL INFORMATION REQUIRED FOR DESIGN

In the preparation of specifications and a layout for a complete foam fire extinguisher system it is necessary to obtain a plan, blueprint, or dimensioned sketch of the oil tankage and adjacent structures, showing their relative sizes and locations. On this plan there should be indicated a satisfactory site for the solution pump house and foam chemical solution tanks. This site should be convenient to the power supply, (the boiler house in case a steam pump is used) as centrally located as possible, and well separated from any serious fire hazard. If possible, several photographs showing the general perspectives should be obtained.

In recommending correct and adequate foam fire protection the following data or information is very desirable:-

Total rated boiler horsepower.

Average boiler horsepower available at all times.

Boiler pressure carried.

Is compressed air available for

agitating the solutions?

What pressure? Capacity of compressor
in cu. ft. per minute.

Electric current. DC or AC? KW available.

DC Av. load volts.

AC Av. load volts phase cycles.

Is water available under city pressure?

If not, what is used and what quantity
can be relied upon?

Are local conditions such that gravity
can be utilized to secure flow of
chemical solutions to oil tanks?

Maximum head in feet available above
top of highest oil tank.

General character of soil (rock, loam,
clay, dry, marshy).

General topography (maximum elevation
of any tank above site suggested for
foam pump house).

Safe bearing power of soil for founda-
tion, in lbs. per sq. ft.

Is it preferable to have pipe lines
laid underground, on the surface, or

carried overhead on stanchions?

Is future extension of oil tankage contemplated?

If so, what is probable amount?

Information should also be obtained regarding the general use, size, construction, number of stories, fire protection installed, and all unusual fire hazards connected with each building.

Are the stills so surrounded with fire walls as to prevent the spread of burning oil to nearby buildings or oil tanks?

It is also desirable to have information as to number, type, capacity, diameter and length of stills, as well as the distance to nearest building or oil tank (with no fire wall or equivalent upgrade intervening).

The following data concerning tanks and agitators should be obtained:-

Capacity, diameter, height or length, type of roof, nature of contents and whether surrounded by fire wall.



OIL TANK FIRES WHERE FOAM FAILED

A careful search of the records available indicates that the first fire upon which foam was used and failed occurred in June 1916, at the Perryman Station of the Gulf Pipe Line Company in Oklahoma. A 55,000 barrel steel wood-roofed working tank approximately two-thirds filled with Oklahoma Crude Oil, was ignited by lightning. One below-ground type of Erwin automatic foam extinguisher had been installed on this tank a year or so previous to the fire. When the fire occurred the fusible links at the top of the tank operated allowing the extinguisher to be brought into action. As chipped soapbark had been used as the foaming ingredient, instead of the pulverized material, the acid pipe became clogged and the extinguisher failed to operate properly, resulting in the loss of the tank. A similar extinguisher on another tank nearby was operated the following day to prove that the failure was due to the chipped soapbark only and not to the mechanical equipment. The device worked effectively and distributed

foam over an entire surface 115 feet in diameter.

During the latter part of 1916 a steel wood-roofed tank belonging to the Tide Water Pipe Line Company, Changewater, New Jersey, was lost due to lightning. Records indicate that this tank was supposed to have been protected by a foam fire extinguisher system in which glue and glucose were used as a foaming ingredient. The main reason for the failure of this system was the fact that the chemical solutions had putrefied and the nature and amount of foam produced was below standard. Such a small amount of solution was stored, that the system would have failed even though good solution had been used. This fire points out the necessity of an adequate solution supply.

On May 30th, 1917, two tanks of the Gulf Pipe Line Company at Perryman Station Oklahoma were ignited by lightning and completely destroyed by the resulting fire. These were 55,000 barrel steel wood-roofed tanks and each was approximately three-fourths filled at the time of the fire. A below-ground type of Erwin

automatic foam fire extinguisher was attached to each tank and arranged to be operated manually as well as automatically. In each case the automatic release operated successfully and the foam generated extinguished the oil fire, but the wood posts within the tanks continued to burn acting as wicks and gradually reducing the foam until the surface again became ignited. The manual release which was located in a box 30 or 40 feet beyond the earthen dike functioned properly when operated, but in neither tank were the burning posts extinguished and the loss was complete. These fires indicate the necessity of being able to supply foam from a hose and also the desirability of having an almost unlimited supply of foam chemical solutions.

On June 15th, 1917 a 93 foot diameter tank belonging to the Standard Oil Company of New Jersey, at the Eagle Refinery Claremont, New Jersey, was ignited by lightning. The tank contained Pennsylvania Crude Oil to the depth of about 17 feet at the time the fire occurred. Although this plant had a foam fire extinguisher



system, no means were provided for introducing foam in this tank. Four two inch steam connections were used and foam was introduced in this way. The amount of foam reaching the fire was of course very small and seemed to have little effect. Later foam was projected over the side of the tank from a larger pipe and after several hours burning the tank contents boiled over. The boiling over occurred several times at intervals of about 20 minutes and the last time the fire extinguished itself leaving four feet of oil unconsumed. Foam cannot really be blamed for the loss of this tank as a good foam was produced, but due to the lack of facilities for introducing it into the tank the fire could not be extinguished.

On July 8, 1917, a 55,000 barrel steel wood-roofed tank of the Gulf Pipe Line Company at Sour Lake, Texas, was ignited by lightning. The tank contained 6 feet of oil at the time of the fire. The foam extinguisher system was immediately started and the foam was promptly turned into the tank and the oil fire extinguished,

but the roof continued to burn on the inside as no foam hose stations were provided as part of this installation. It was decided to let the roof burn and extinguish it with foam after it fell. When the roof did the interior rectangular mixing box and foam ladders were carried below the surface of the oil and the tank became ignited a second time from the burning wood. When the foam solutions were pumped into the tank again they did not generate foam as no means of mixing were present. From the above it will be noted that the main reasons for the failure of the foam system were the use of interior mixing chambers and the lack of foam hose stations.

At Skiatook, Oklahoma, April 16, 1918, lightning ignited a 55,000 barrel steel wood-roofed tank of the Sinclair-Cudahy Pipe Line Company. The tank was supposedly protected by a "homemade" foam fire extinguisher device. Foam was pumped into the tank for a period of about 15 minutes and was showing some effect on the fire when two globe valves blew out at a point

in the lines near the pump. After these were repaired and the system again put into operation, two tees inside of the dike wall burst. An attempt was made to repair this break, but the heat from the burning oil was too intense for the operators and further efforts to use the foam system were abandoned. The failure of this system can be accounted for very easily by noting the above statements. The total capacity of each solution tank installed was only 300 barrels.

During July 1918, two tanks of the Standard Oil Company of California at El Segundo, California, were struck by lightning and ignited. One of these tanks was connected to the foam fire extinguisher system at the plant and the oil fire was successfully extinguished but the roof continued to burn, as the operator of the system had shut down the foam solution pump in order to reserve the chemical solutions in case another fire occurred in the plant. After the storm had subsided the remainder of the solutions were pumped into the tank, but were not successful in putting out the fire. From records

available the installation undoubtedly employed a foam ladder and had no means of hose station operation.

A 55,000 barrel steel wood-roofed tank containing three feet of pressure distillate was ignited by lightning September 4, 1918, at the tank farm of Cosden & Company, West Tulsa, Oklahoma. One man located at the west end of the tank farm saw the lightning flash and immediately ran to the valves on the foam system and opened the two valves leading from the cross lines to the particular tank that was burning. He then hastened to a telephone to give the alarm. Shortly after this an employee who had seen the flash and started the solution pump came out in an automobile to the burning tank. He went to the two valves and not knowing they had been opened, turned them the only way he could, thinking he was turning them on. His action resulted in the closing of both valves before the foam solutions had a chance to enter the tank or do any good. The valves remained closed until 5 or 6 hours after the fire started. The loss of this



tank proves very conclusively the necessity of rising stem or indicating valves in the field layout. Had such been used the valves opened would have been allowed to remain open.

On July 13, 1919, a 55,000 barrel steel tank of the Pure Oil Division of the Ohio Cities' Gas Company, Marcus Hook, Pennsylvania, was ignited by lightning. The tank had a wood roof and contained about 30,000 barrels of Oklahoma Crude Oil at the time of the fire. The foam system at this plant was one designed and installed by the Pure Oil Company and is one of the earliest foam systems ever erected. The two chemical solutions are discharged into a single six inch line near the pump so that the foam is created in the discharge pipe. The foam was then pumped several hundred feet to the burning tank where it entered at such a velocity that it went below the surface of the burning oil. The complete loss resulted. The main reason for the loss of the tank appears to be the lack of adequate solution supply, while possibly a contributing cause may have been the friction and

pressure breaking down the foam in the pipe line. The foam ladders employed in this tank were found lying inside of the tank intact after the fire and it would be interesting to know whether they were displaced by an explosion, and just when they fell from their original positions.

The Indian Refining Company, Lawrenceville, Illinois, on August 6, 1919, lost a 37,000 barrel tank containing 30,000 barrels of refined gasolene. The fire was caused by lightning. An investigation of this fire brought out the facts that the foam fire extinguisher system was in proper operating condition, but that the foam chemical solutions had deteriorated. Fourteen months prior to the fire the owner of the installation was advised that one of the foam chemical solutions should have been replaced as it had become deteriorated due to excessive air agitation. After the first batch of chemicals had been exhausted the operators of the system attempted to prepare 50,000 gallons of each solution in a period of about three hours. As the solutions were not completed the second batch

had very little effect on the fire and did not succeed in extinguishing it. The result of this fire shows the absolute necessity of regular and systematic follow-up so that such negligence would be noticed and conditions remedied.

During September 1919, two oil tank fires occurred at Sabine Pass, Texas, in the Sun Company's Station. In each case a 55,000 barrel wood-roofed steel tank was lost. Each tank contained Ranger Crude Oil, the first being a little less than half full, while the second contained only a small amount. The first tank was struck by lightning on September 5th, and it was estimated that foam entered the tank 5 to 7 minutes after it was struck. When the lightning struck the tank, the roof was blown into the air and most of it fell back into the tank. Of course, a great deal of the roof remained above the oil and it is thought that the wood burning above the oil prevented the foam from smothering the fire. In about 30 minutes the top ring caved in which rendered the foam mixing chambers useless. A temporary mixer was prepared, but by the time

it was arranged the tank boiled over. The loss of oil due to this fire was approximately 15,500 barrels. The second tank fire occurred under similar conditions to those encountered during the first fire. The roof fell into the tank and shortly after the sides of the tank caved in. As there was only a small amount of oil in the tank, no attempt was made to pump any of it out. Tests of the foam solutions showed that they had the proper expansion. An inspection of the plant revealed the fact that the pump capacity was inadequate and the chemical solution lines too small. There is also the possibility that the solutions were not up to proper standard. The main reason for the loss of this tank seems to be the inability to pump solutions into the tanks rapidly enough to form a covering of foam before the fire destroyed it.

The above fires include all the tank fires where foam was used and failed, or apparently failed. Where these apparent failures of foam have occurred the reason has always been directly due to the fact that the system has not

been installed in accordance with the simple requirements of the standard practice now developed. An inadequate supply of the foam chemical solutions, insufficient pumping capacity, undersized piping, mixing chambers incorrectly devised and wrongly installed, are bound to defeat the very purposes intended.

OIL TANK FIRES WHERE FOAM WAS SUCCESSFUL

The efficiency of the foam fire extinguisher system has been demonstrated in actual oil tank fires under widely varying conditions as will be noted below.

On July 19, 1916 three gasoline tanks belonging to the Gulf Refining Company, Port Arthur, Texas, were ignited by lightning. All were steel tanks with wood type roof construction. Tank No. 850 was 70 x 10 feet, capacity 6780 bbls., and contained about 4200 bbls. when ignited. Tank No. 855 was 65 x 10 feet, capacity 5865 bbls., and contained when struck, about 3500 bbls. Tank No. 857 was 90 x 30 feet, capacity 33,750 bbls., and contained, when ignited, 27,619 bbls. The fire in the largest tank was extinguished in six minutes and in less than thirty minutes all three fires were out with a loss of less than one half of one per cent of the total volume of gasoline involved. Here is a demonstration under three separate conditions:- First - Top blown off by explosion, mixing box exposed and burning wood obstructions. Second - Top partly wrecked by

explosion. Third - Top intact and not disarranged. The top of Tank No. 855 had blown up at least ten feet and precipitated in pieces into the tank, leaving the center pole sticking up above the top and the rafters heading into the tank. Top of Tank No. 850 was not damaged to any great extent, the fire burning around the edge of the roof and put out with the top intact; while in the large tank, No. 857, there was a minor explosion which buckled the roof and made an opening of approximately 10 x 20 feet. Thus, there is a demonstration the three classes of steel tanks with wood roofs,- one with the top blown off and falling into the tank, and the rafters and metal retarding the action of the foam; the other with the top partly blown off; and the last with the top intact. The total quantity of solution used was approximately 15,000 gallons.

On July 21, 1916, a 94 ft. diameter steel tank of the Southern Pipe Line Company, Millway, Pa., was struck by lightning and ignited. The tank capacity was 35,000 bbls., but it contained only 26,000 bbls. of Oklahoma crude oil at the time of the fire. The wooden roof was

covered with sheet iron plates of No. 18 gauge. At the time of the fire the regular foam solution pump was out of service, but two separate spare pumps were employed. The roof fell in immediately, but held partly to the wall of the tank, making an inverted cone. The foam entered the annular space surrounding this cone, but was not able to reach the oil burning in it. Hose lines were attached to the foam hose connections and turned into the center of the tank. At about the same time the cone split, allowing the foam in the annular space to reach the center. Twenty-five minutes from the time of ignition the oil fire was extinguished. This fire, fought under very adverse conditions, illustrates the advantage of being able to apply foam through a hose.

At the Port Arthur refinery of the Gulf Refining Company, on August 7th, 1916, lightning ignited a 55,000 barrel steel wood-roofed tank containing 48,000 barrels of light gasolene distillate. The foam pump was put into operation immediately and in spite of the fact that a brisk wind was blowing at the time the

foam was applied the fire was easily extinguished. There was but little loss of oil even though the roof was entirely destroyed.

At the Fort Worth refinery of the Gulf Refining Company, on August 23d, 1916, lightning ignited a 37,500 barrel steel wood-roofed tank containing 36,600 barrels of light gravity crude oil. At the time of the fire, there was a strong wind accompanied by heavy rain and hail. The entire roof of the tank was blown off and fell on the two valves at the earthen dike, breaking one of the stems and making it necessary to open the valves with pliers before the foam could be used. The fire was extinguished in less than twenty minutes although some of the wood uprights in the tank continued to burn longer. The conditions at the time of this fire were very severe, the wind blowing strongly and the rain being heavy. Owing to the high level of the oil in the tank the wind blew a considerable amount of foam off of the surface. Even under these adverse conditions the fire was extinguished, the loss of oil being comparatively small.

On July 14, 1916, at the Kendall Refining Company, Bradford, Pa., the filter house was practically destroyed by fire. At the time a foam fire extinguisher system had been partially installed and the nearest hose connection was about 200 feet from the fire. However, the use of the foam was very successful in saving the wax plant, which adjoins the filter house, and it was only a few minutes after the stream of foam was brought into use that the fire was under control.

A fire at the Atlas Refinery, Los Angeles, California, on January 2, 1917, presents certain interesting features which make it worthy of notice. Residuum, at a temperature of 550°F. was being discharged into a closed tank 22 feet in diameter and 15 feet high. As there was no foam extinguisher system at this refinery steam was tried on the inside of the tank while water was applied to the outside. The fire proved uncontrollable by such means. After the fire had burned four hours a supply of foam chemical solutions was secured in a tank wagon from the

General Petroleum Corporation and applied to the fire by hastily improvised methods. The fire was so hot that the tank sides were cherry red and the elbow on the end of the 4-inch pipe used was burned off before the foam issued from it. The fire was completely extinguished four minutes after the foam started into the tank. This fire indicates that foam will act effectively on heavy boiling residuum even after the fire has been burning for a long period. Furthermore, the red hot sides of the tank did not affect the foam sufficiently to have any appreciable effect on the result.

At the Eagle Refinery, Standard Oil Company of New Jersey, Claremont, N. J., on August 2, 1917, a 50 foot steel-roofed steel tank 35 feet in height was ignited by lightning. At the time of the fire the tank contained paraffine distillate to a depth of seven feet two inches. The roof was blown off in one piece and fell, folded in half, clear of the tank. The refinery was provided with a foam system, but this particular tank had not yet had the per-

manent connections made to the foam lines. A line of 2-inch pipe was hastily run over the side of the tank with a tee at the bottom and connection at the top so as to discharge the foam down into the tank. Pipes were run from the foam lines to the tee at the bottom of this 2-inch pipe and foam discharged into the tank about 35 to 40 minutes after the fire started. The fire was extinguished about twenty minutes later with a relatively small loss as the tank can be straightened and rebuilt.

On August 16, 1917, a receiving tank at the Pure Oil Company's refinery at Marcus Hook, Pa., was struck by lightning and ignited. The tank contained about 46,000 gallons of crude naphtha. The foam lines were set, the pump started and foam entered the tank about ten minutes after the fire started. The tank was burning around the edge and through the hatches at that time. When the foam had covered the fluid the gas in the tank still continued to burn, but gradually died down and as the tank had a wooden roof the wood continued to smolder and burn for

about one hour. This shows plainly that when oil in a tank is covered with foam it will not catch fire. There is no doubt that without foam the loss would have been heavy and the refinery temporarily shut down. Measurements showed that approximately 158 bbls. of each Foamite chemical solution were used.

At the Sun Company, Marcus Hook, Pa., September 25, 1917, a 93 foot tank partially filled with heavy Texas crude oil caught fire from burning brush. Not having a foam system, the fire burned for four and one half hours before temporary connections could be made to the PureOil Company's foam system over one quarter of a mile away. Meantime the tank collapsed and the oil boiled over. Foam was applied from a hose and the burning oil on the ground was extinguished in ten minutes. Twenty minutes later the fire in the tank was extinguished. It should be noted that the roof and the sides of the tank had fallen into it making a mass of material that the foam had to surmount and adding greatly to the difficulty of extinguishing

the fire. The tank was, of course, red hot before it collapsed, and the oil boiling, as it had been burning furiously for over four hours, in addition to which it was warm before catching fire due to the fact that it had been heated from steam coils. The conditions at this fire were particularly severe.

A number of fires have occurred in most inaccessible places at the plant of the General Petroleum Corporation, Vernon, California. On October 23, 1917, hot oil became ignited in the sump under heat interchangers of a Trumble Unit. The fire was quickly and easily extinguished by foam from a hose station before any damage could be done. On November 17, 1917, a gasket on a flanged pipe fitting failed on a crude oil heating coil of a Trumble unit and oil was ignited from hot furnace walls. Foam was applied from hose stations and the fire extinguished in less than five minutes. On December 24, 1917, a gasket failed on a crude oil heating coil of a Trumble unit and the crude oil, at a temperature of 350° F. and a pressure in excess of 30 lbs., spurted

against the hot furnace walls and ignited. The fire was easily and quickly extinguished by the foam applied with a hose line.

At the Vernon Oil Refining Company, Vernon, California, on March 3, 1918, the back-fire of an automobile motor ignited gasolene which caused the ignition of six supply wagons, which in turn set fire to a 2000 bbl. reservoir. After the fire had been burning for forty five minutes foam solutions were brought to the fire by tank wagons from the foam system of the General Petroleum Corporation near by. The solutions were applied by means of two small pumps and a piece of pipe, and the fire quickly extinguished.

On April 18, 1918, a 37,500 barrel steel tank belonging to the Gulf Pipe Line Company at Big Sandy, Texas, was ignited by lightning. The tank contained Oklahoma crude oil to a depth of about five feet six inches. The entire roof was blown up, one half falling inside of the tank while the rest fell outside of the tank into the fire wall. The foam system was put into

operation immediately and foam entered the tank three minutes after the fire started. The shell of the tank was red hot within two minutes. The foam commenced to take effect as soon as it entered the tank but the fire was not extinguished until forty five minutes later, due to the fact that the roof fell into the tank in such a manner as to block off one quarter of the area. As the system was not equipped with means for applying foam through hose lines, it was necessary to continue pumping in foam until this roof was burned up and covered. About 600 barrels of each foam had to fall twenty five feet through the draught and flames before reaching the oil. After the fire the tank was in such condition that the five top rings had to be redriven and caulked and several buckles pulled out of one side. This fire proved conclusively several things:- First, that foam will drop to the bottom of a burning tank in spite of the upward draft caused by the flames. Second, that foam may drop this distance and still operate effectively in spite of the heat. Third, that foam is not affected by the

red hot sides of the oil tank sufficiently to have any effect on its fire extinguishing powers.

These fires cover oils of every description, from the lightest to the heaviest petroleum products, and in tanks of various sizes and construction, some with wood and others with steel roofs. The conditions were natural in every instance - not pre-arranged, and they were very severe. The fires were extinguished so promptly that the loss of oil was negligible, and the damage to the tanks confined to the roofs, due to the initial explosion.

BIBLIOGRAPHY

Herewith is presented a bibliographic list of articles and papers referred to in writing this thesis:

Redwood, Sir Boerton, A Treatise on Petroleum, Vol. I, II and III, 1913.

Bowie, C. P. Bulletin 155, Bureau of Mines Oil Storage Tanks and Reservoirs.

Bowie, C. P. Bulletin 170, Bureau of Mines Extinguishing and Preventing Oil and Gas Fires.

Eng. News. Vol. 75, April 27, 1916.

Fuel Oil Journal Vol. 6, July 1915.

Fuel Oil Journal Vol. 6, August 1915.

Fuel Oil Journal Vol. 7, Sept. 1916.

Fuel Oil Journal Vol. 7, Oct. 1916.

Mining and Oil Bulletin. Vol. 2, Feb. 1916.

Natural Gas Journal. Vol. 10, April 1916.

Oil and Gas Journal. Vol. 13, March 11, 1915.

Oil and Gas Journal. Vol. 14, Oct. 21, 1915.

Oil and Gas Journal. Vol. 15, June 15, 1916.

Petroleum Age Vol. 2, July 1915.

Pop. Science Monthly. Vol. 88, Jan. 1916.

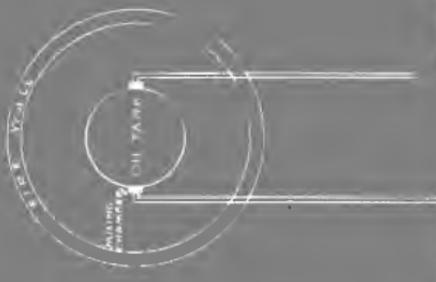
Safety Engineering. Vol. 32, Sept. 1916.

Scientific American Vol. 115, July 8, 1916.

PIPING
TO
MIXING CHAMBERS
PLATE I

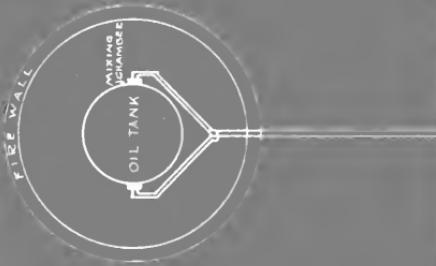
CORRECT

CONTINUOUS
CONTINUOUS
CONTINUOUS
CONTINUOUS



INCORRECT

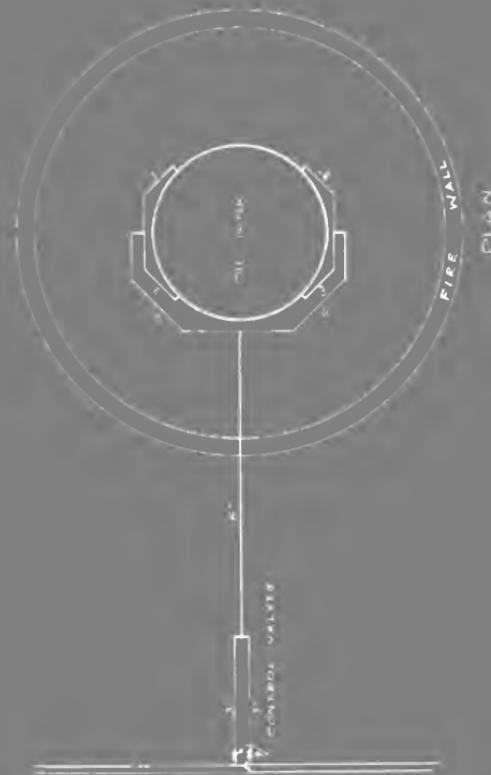
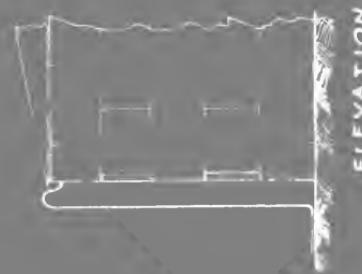
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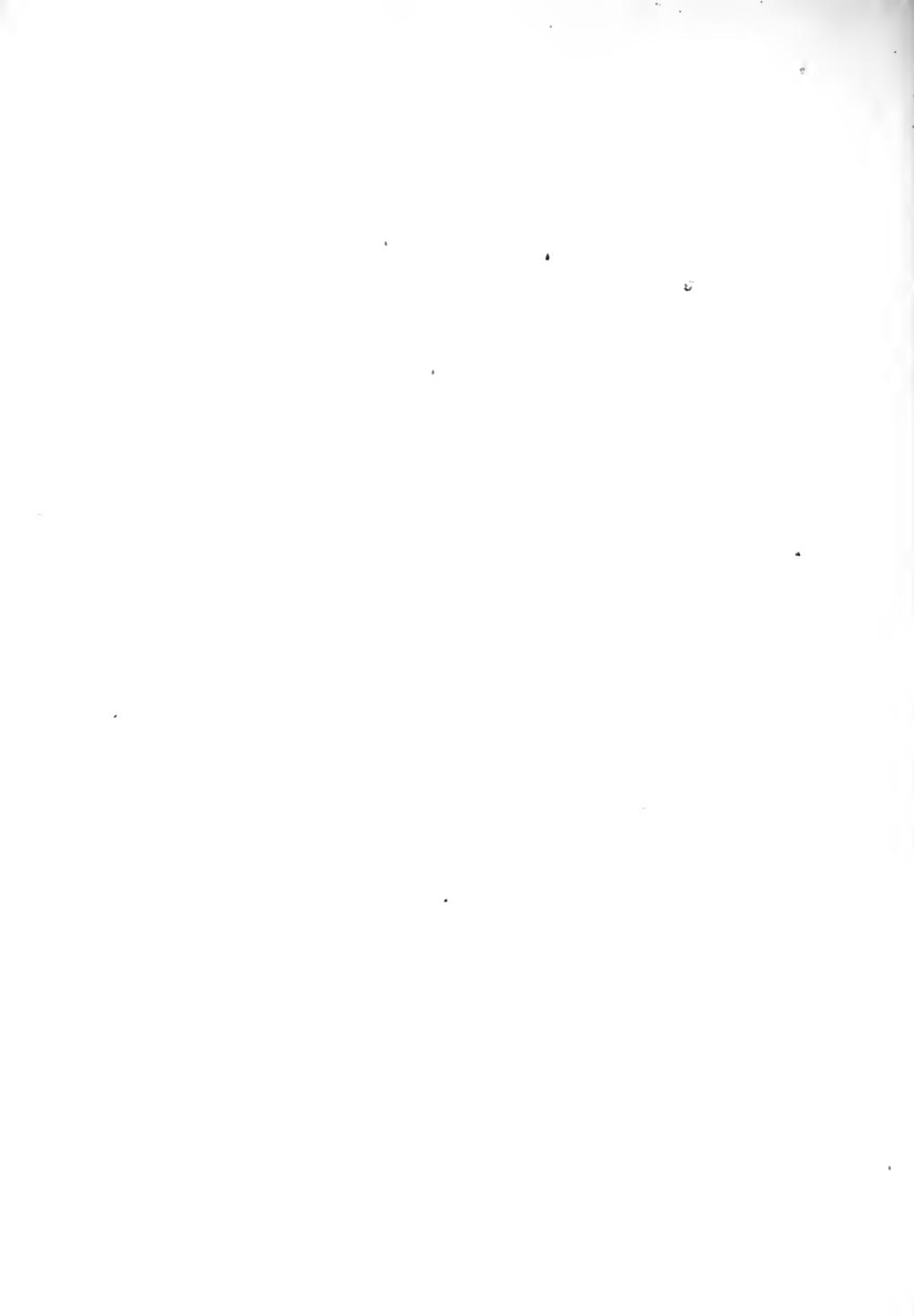




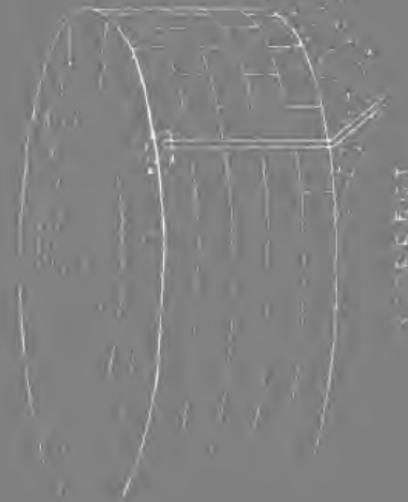
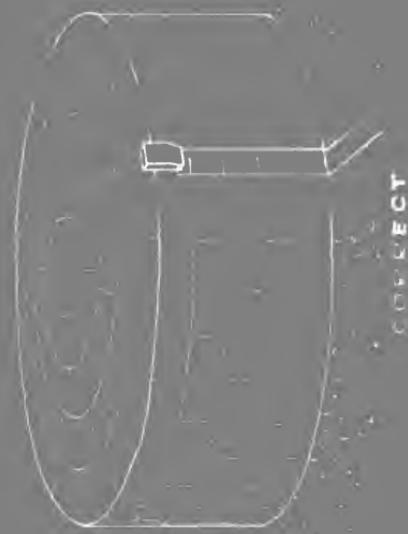
INCORRECT USE
OF
STEAM LINES FOR FOAM

PLATE 2.

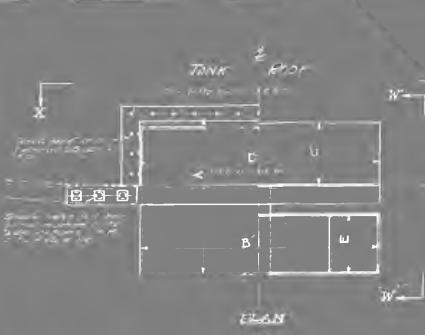




LOCATION OF
MIXING CHAMBERS
ON TANKS
PLATE 3.

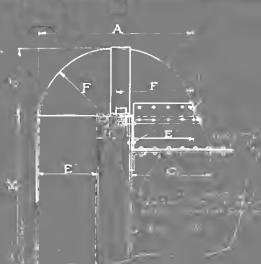






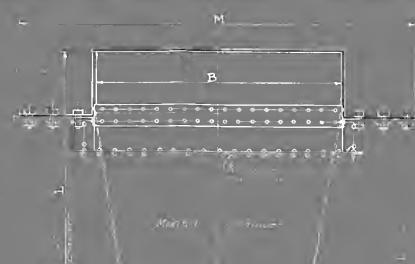
PLAN

①



FRONT ELEVATION

②



SIDE ELEVATION

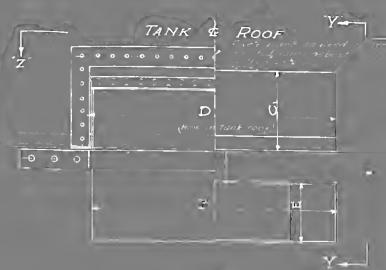
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SECTION W-W

④

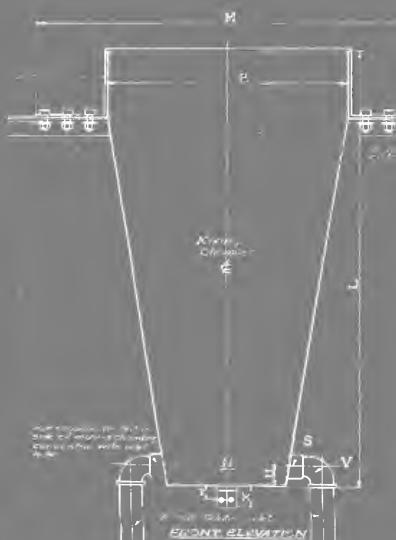
SECTION X-X

⑤



PLAN

⑥

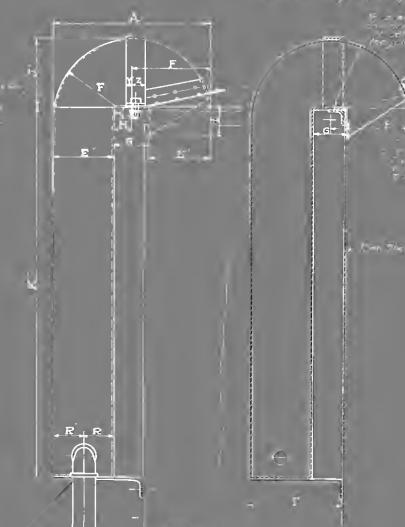


FRONT ELEVATION

⑦

PLAN BOTTOM

⑧



SECTION W-W

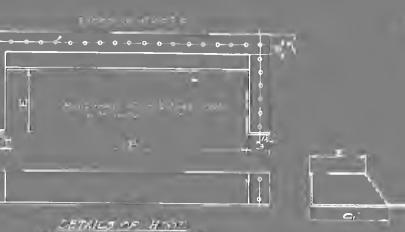
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LOCATION OF HOLES IN PLATE
FOR TYPE 'M' MIXING CHAMBERS

⑩

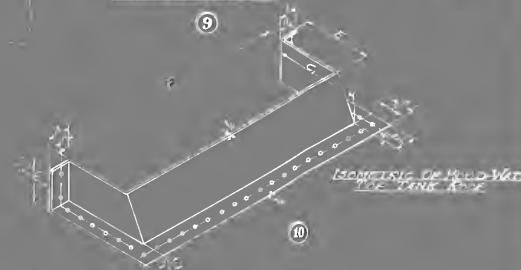
LOCATION OF HOLES IN PLATE
FOR TYPE 'N' MIXING CHAMBERS

TYPE LA	TYPE MA	TYPE NA
A	11	14
B	6	10
C	9	11
D	11	9
E	7	8
F	5	4
G	5	4
H	7	3
I	7	1
J	5	1
K	3	3
L	2	2
M	10	20
N	12	12
O	5	6
P	4	3
Q	4	3
R	4	3
S	100	100
T	10	10
U	3	3
V	3	3
W	3	3
X	3	3
Y	1	1
Z	2	1



DEPTH OF HOLE
WATER IN TANK SIDE

⑪



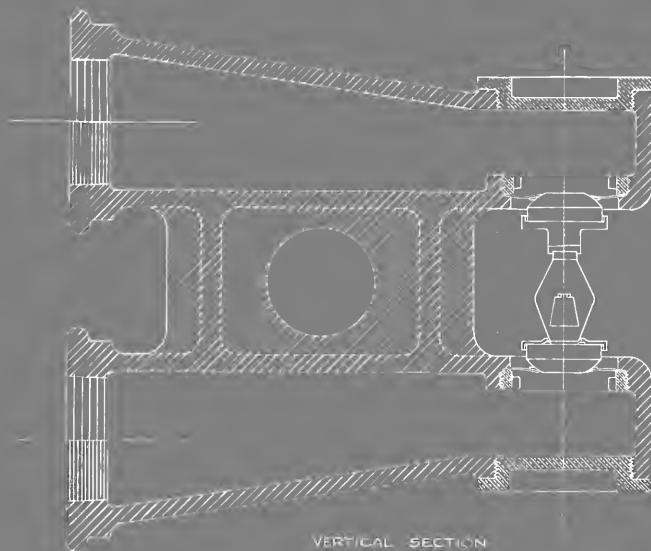
LOCATION OF HOLE WATER
TOP TANK SIDE

⑫

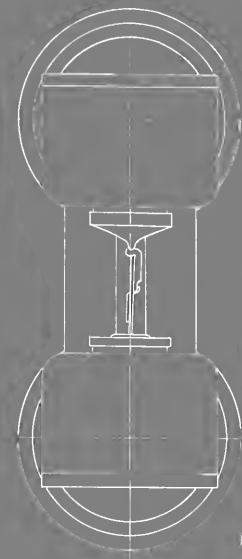
PATENTED
TANK & ROOF
TYPE 'LA' & 'MA'
ATTACHMENT

CONSTRUCTION & ATTACHMENT
TYPES LA-MA & NA
FOAMITE MIXING CHAMBERS
PLATE 4

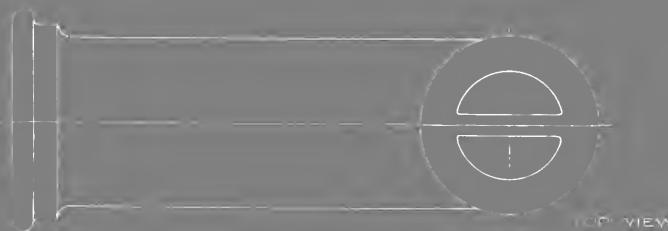




VERTICAL SECTION



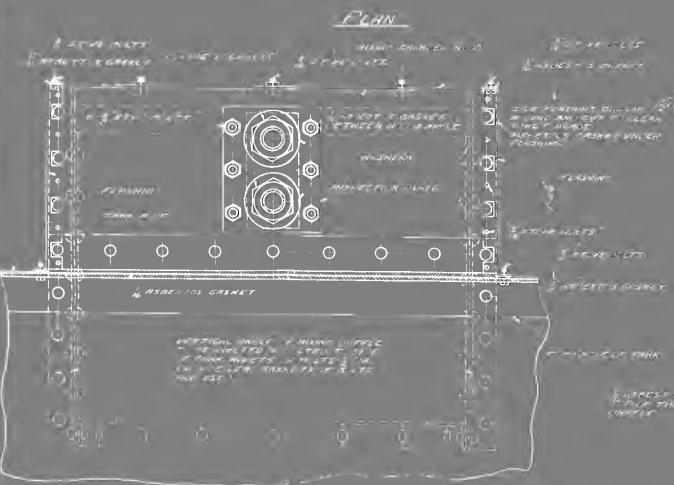
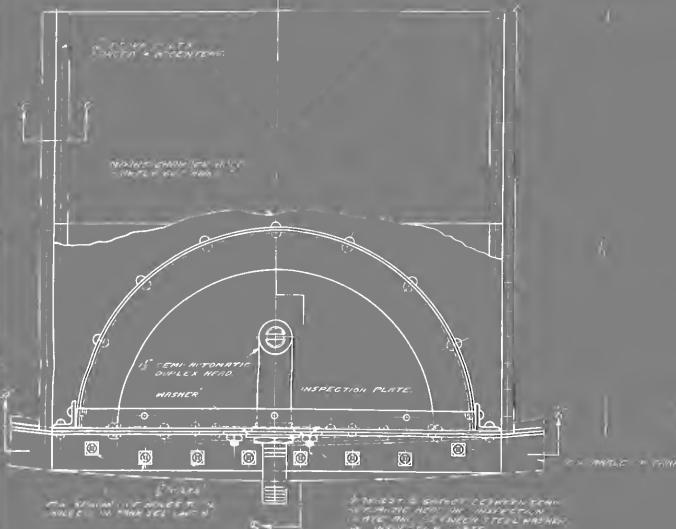
END ELEVATION



TOP VIEW

FOAMITE SEMI-AUTOMATIC
DUPLEX HEAD
PLATE 5

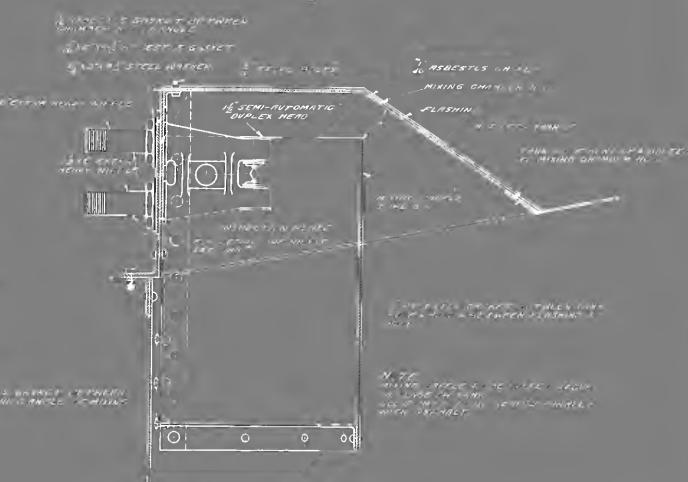




SECTION A-A



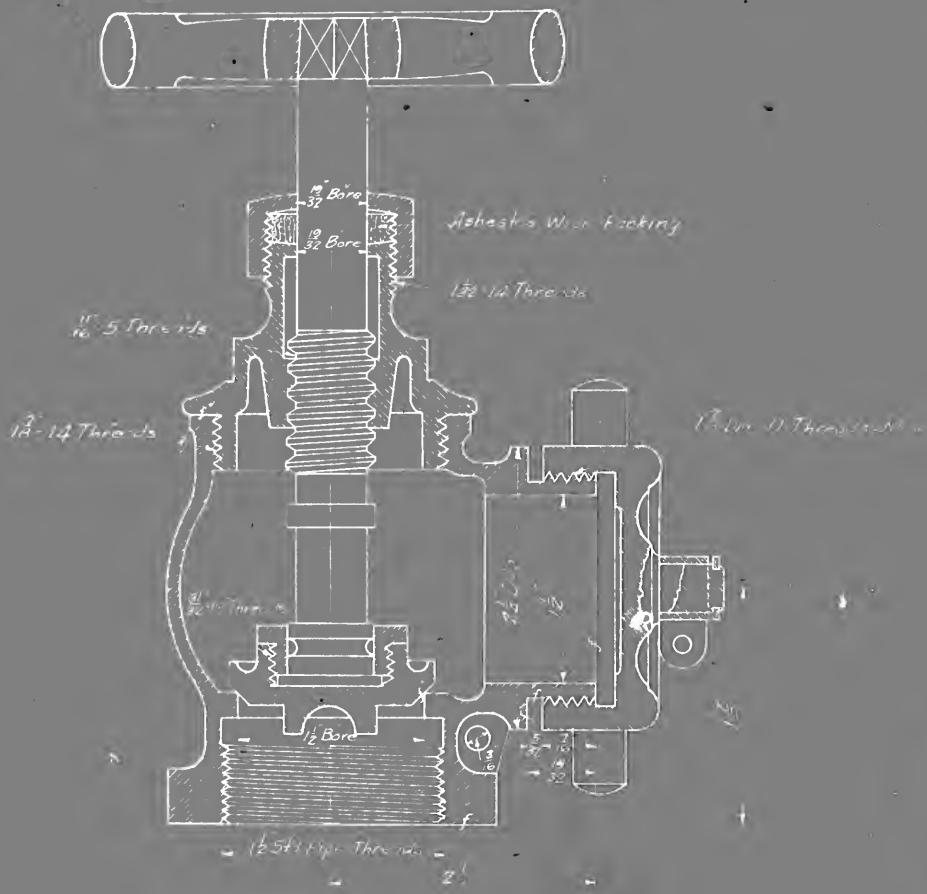
SECTION C-C



SECTION B-B

SEMI-AUTOMATIC DUPLEX HEAD
AND MIXING BAFFLE
METHOD OF INSTALLING ON OIL TANK
PLATE 6.





ASSEMBLY OF 1½" FOAMITE HOSE ANGLE VALVE

PLATE 7.

